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Memo

date: *August 28, 2009*

to: *RSC*

from: *D. Beavis* DB

subject: *Extending Routine Operations of RHIC and AtR to Low Energies*

Motivation

The physics program at RHIC has been approved to measure the properties of strong interacting matter created in ion collisions at energies well below the initial design energy of RHIC. Since the loss patterns and the injection frequency[1] is substantially different from what was analyzed in the original RHIC SAD[2] and supporting documents it was decide that a USI was appropriate for approving this new routine mode of operation. The RHIC ASE[3] does not require modification.

The RHIC program would like the minimum routine injected energy to be as low as possible consistent with the RHIC ASE and ALARA principles. Due to decreasing beam lifetimes with decreasing injection energies it is expected that initial operations will limit the time at the lowest energies until the lifetimes of these low energy beams can be extended.

The program would also like to have this capability to operate at low energy for all beam species from protons to gold. For the next few years it is expected that the low energy program will only use gold ions but it may become desirable to use other ions. Once the loss patterns are established for one ion species such as gold other ions can be compared for losses and appropriate operations procedures can be adjusted as needed to comply with the ASE and ALARA principles.

Reference 1 suggests some likely operating scenarios for FY10 low energy operations. In addition, it mentions likely operating parameters such as bunch intensity, fills per hour, no acceleration. None of these operating parameters are assumed to be restricted in the radiological analysis unless it is stated in the analysis.

The RHIC ASE has a series of radiological conditions that must not be exceeded. Section 5.1.1 and Section 5.1.3 place limits on the total beam energy that can be in each ring. These conditions will be addressed below. Section 5.1.5 addresses exposure limits at collider areas and will be addressed in other documents. Section 5.12 has exposure limits for non C-AD areas and groundwater limits. These will also be treated in other documents.

Beam Limits per RHIC Ring (RHIC ASE 5.1.1 and 5.1.3)

It is convenient to discuss the beam limits in nucleon GeV since to lowest order the transverse radiation scales closely with GeV-nucleons. As noted in Sullivan[4] the actual scaling of transverse dose goes as $E^{0.8}$ rather than E. Using E to extend to higher energies provides a conservative estimate but not when extrapolating to lower energies. Therefore, we will extrapolate to lower energies using $E^{0.8}$. Scaling the Au equivalent beam limits (sec. 5.1.1) to the proton beam limit (sec. 5.1.3) with the $E^{0.8}$ energy scaling the limits are found to be essentially equal. Since most of the analysis of RHIC was conducted for 250 GeV protons this is the limit we will scale as a function of energy.

The basis for a limit on the amount of nucleon-GeV per ring is related to machine failures that can cause most of the beam to be lost in as short as tens of microseconds. These potential

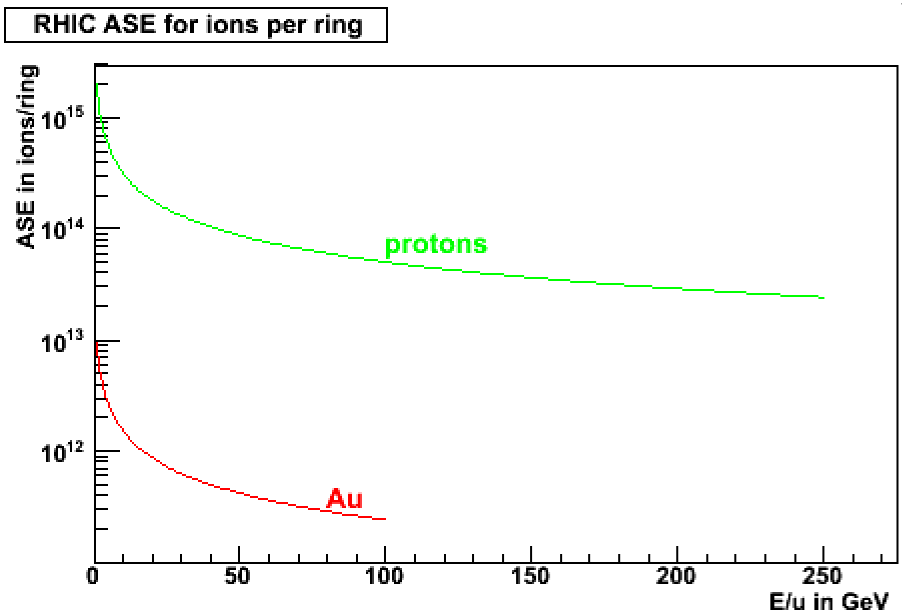

Figure 1. The RHIC ASE as a function of Energy per atomic mass unit.

beam faults established most of the shielding requirements for RHIC since they are thousands of times higher than routine chronic beam losses as analyzed in the original documents. The proton limit can be restated as the beam per ring must be less the $2.4*10^{13}*(250/E)^{0.8}$. Figure 1 shows this limit as a function of energy. As an example the beam intensity would have to be 80 times higher at 2.5 GeV than for normal full energy running to reach the ASE limit. Figure 2 display the ASE limit for bunch intensity assuming there is 120 bunches. Usually there are less bunches to allow for an abort gap.

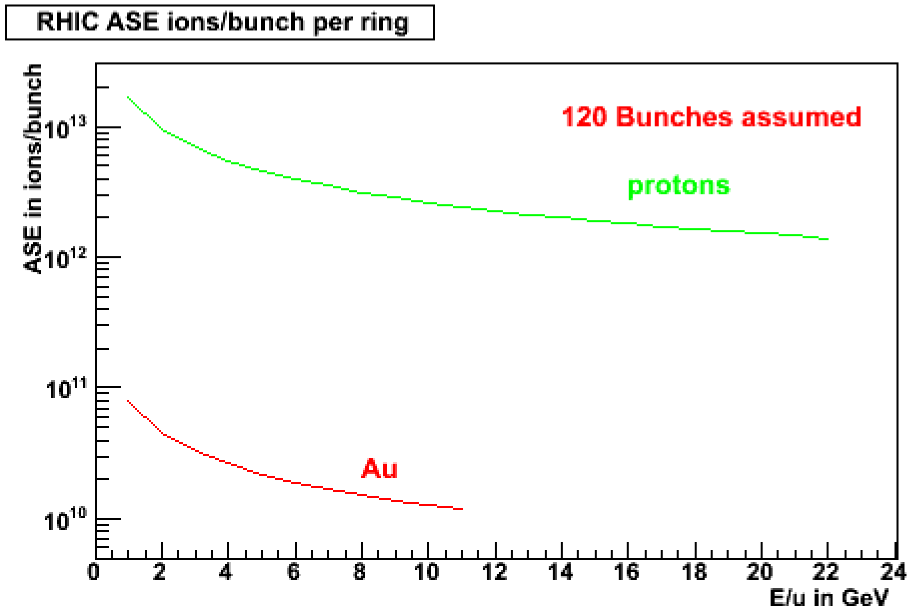

Figure 2. RHIC ASE for bunch intensity as a function of energy per atomic mass unit.

The Au bunch intensity has never reached $2*10^9$ Au ions. It is therefore trivial to satisfy ASE beam limits for Au. The un-polarized proton source is capable of delivering bunches at intensities higher than the present RHIC ASE. Typically this source is not used for RHIC unless the polarized proton source is being serviced. C-AD already has hardware and procedures in place to prevent exceeding the ASE for protons, either polarized or un-polarized.

The radiation in the forward direction does not scale with energy like the transverse radiation. In the near zero-degree region the radiation scales faster than E. Muons can be a concern for any forward shielding with the dominate contribution coming from the decays of pions. The RHIC berm was designed with muon spurs to reduce muons to an acceptable flux outside the berm[5]. The flux of muons in the forward direction scales with energy[6] as E*exp(-st/E), where s is a parameter related to the shielding, t is the shielding thickness, and E is the nucleon energy. The muon flux will decrease more than the allowed rise in the ion intensity and is therefore not an issue for low energy operations.

The dose due to hadrons in the forward direction increases faster than the energy. The dose at 0^0 per interacting nucleon[7] decreases a factor of 4000 when the energy is changed from 250 GeV to 10 GeV. At lower energies it will be even lower. If the energy is changed from 100 GeV to 10 GeV then the dose decreases a factor of 400. The radiation issues are lower beam energies will not be an issues for exterior dose.

It is concluded that the procedures and systems in place for operations to comply with the RHIC ASE sections 5.1.1 and 5.1.3 are more than sufficient for routine operation of low energy beams.

Other RHIC ASE sections on radiological conditions will be addressed in additional notes.

References

1. T. Satogata, "RHIC Low Energy Beam Loss Projections", August 25, 2009.
2. RHIC SAD.
3. See C-AD OPM 2.5.2.
4. A.H. Sullivan, A guide to Radiation and radioactive Levels Near High Energy Particle Accelerators, Nuclear technology Publishing, 1992.
5. A. Stevens, "Radiation from Muons at RHIC", AD/RHIC-46, Feb. 1989.
6. See reference 4 section 2.3.2.
7. See reference 4 section 2.2.2.

CC:

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